Paving the Way for EHVs

(Environmental Hybrid Vehicles)

Hybrid Electric Vehicles:
Here and Now TOPTEC
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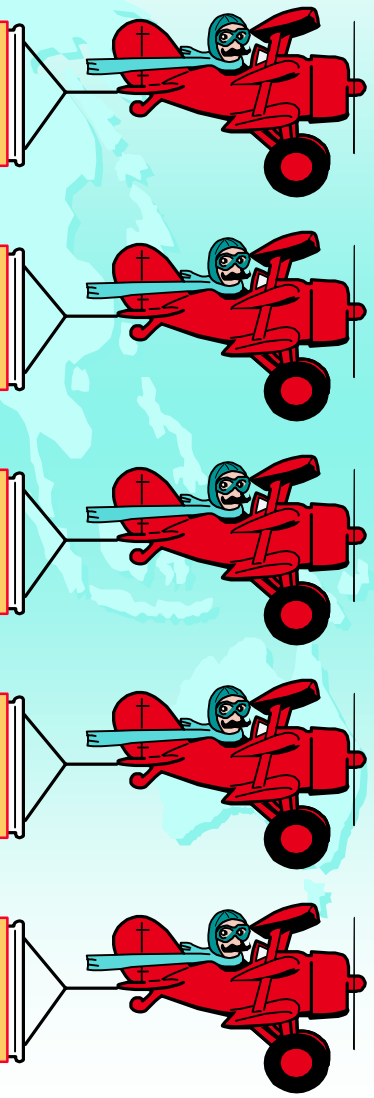
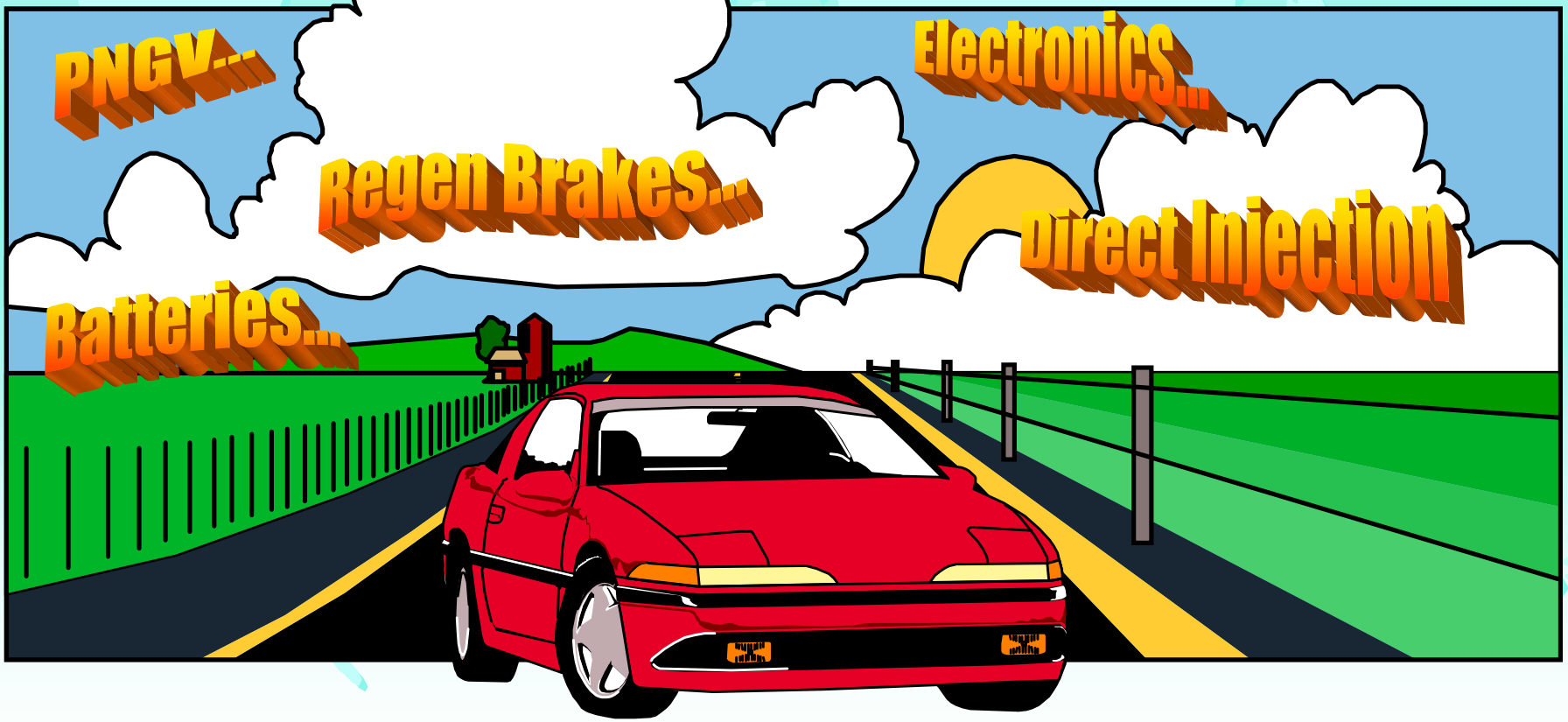
Lessons From the Past: Transportation Revolutions Can Occur *Rapidly*

What Made Such Rapid Change Possible?

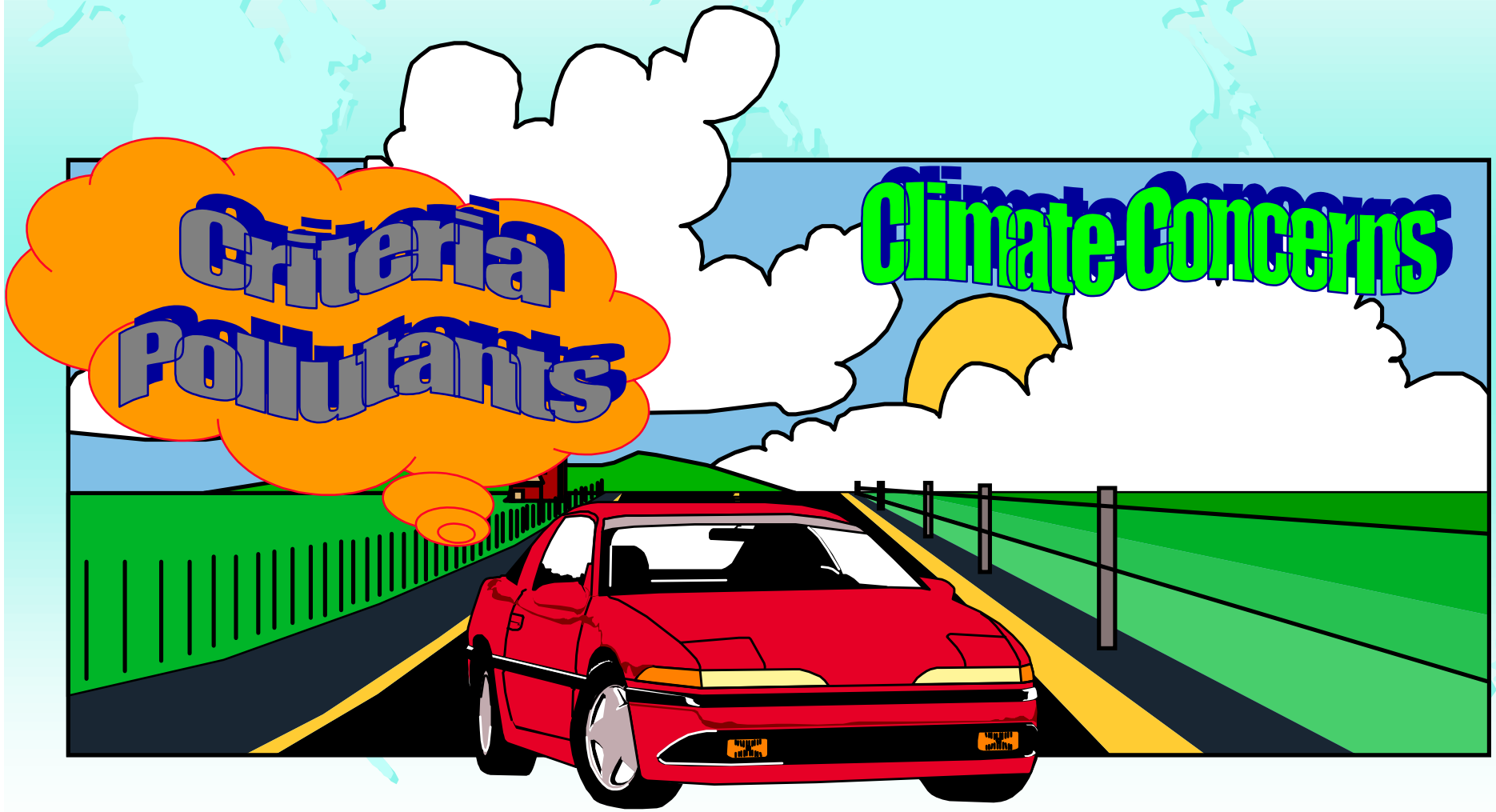
- Leapfrog Technology
- Value to the Consumer
- Risktaking Businesspeople
- Powerful Government Policy
- Public Environmental Concern



Hybrids: The Next Transportation (R)Evolution?



Why *Environmental* Hybrids?



Vehicles Still Contribute to Unhealthy Air for Millions

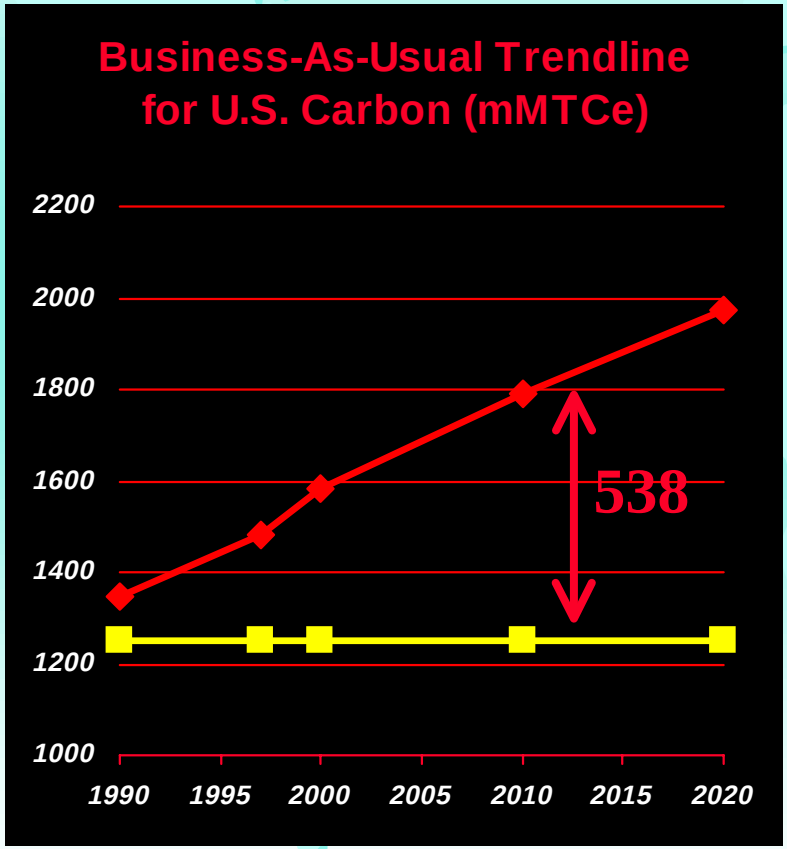
Pollutant	1991 Nonattain-ment Areas	1998 Nonattain-ment Areas	1998 Population
CO	42	20	34M
O_3	100	38	100M
PM_{10}	70	77	30M

Source: National Air Quality and Emissions Trends Report (EPA/Dec. 1998)

Criteria Emission Standards Will Continue to Tighten

- New National Ambient Air Quality Standards (NAAQS)
- National Low Emission Vehicle Program (NLEV)
- Tier 2 just around the bend
- CARB LEV II
- Importance of in-use evaporative emissions

Climate: What is the "Seven Percent" Solution?



- Kyoto target:

  7% below 1990 levels by 2008-2012

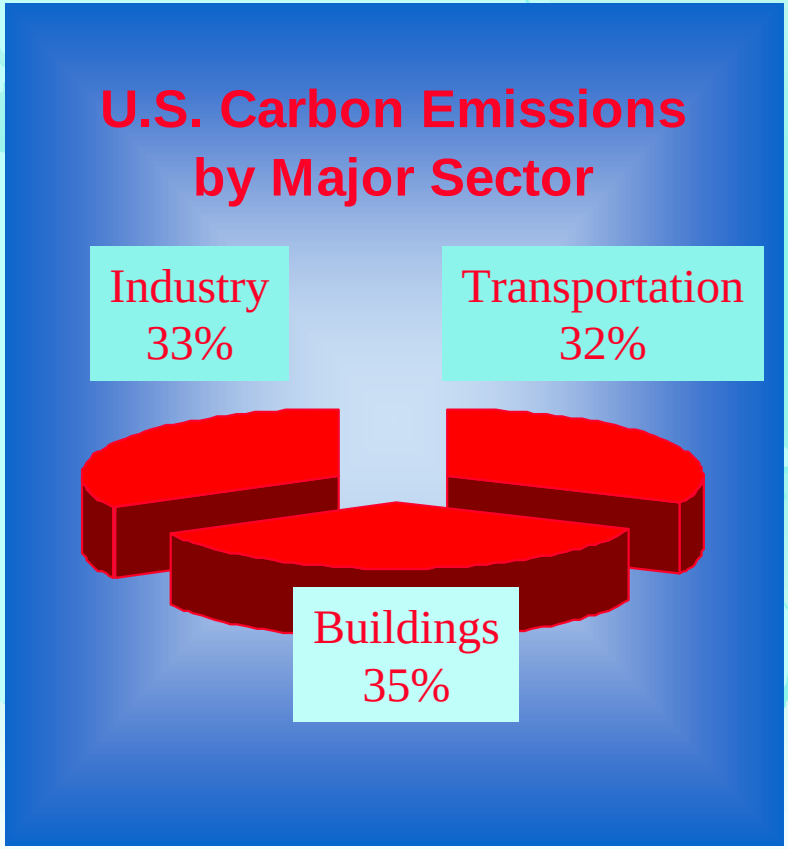
- Implied reduction from 2010 business-as-usual-case:

  538 mMTCe (30%)

based on DOE projections

Transportation is 1/3 of the U.S. Greenhouse Pie

- Fastest growing, most complex sector
- More trucks, VMT growth, flat new vehicle fuel economy all drive the trend

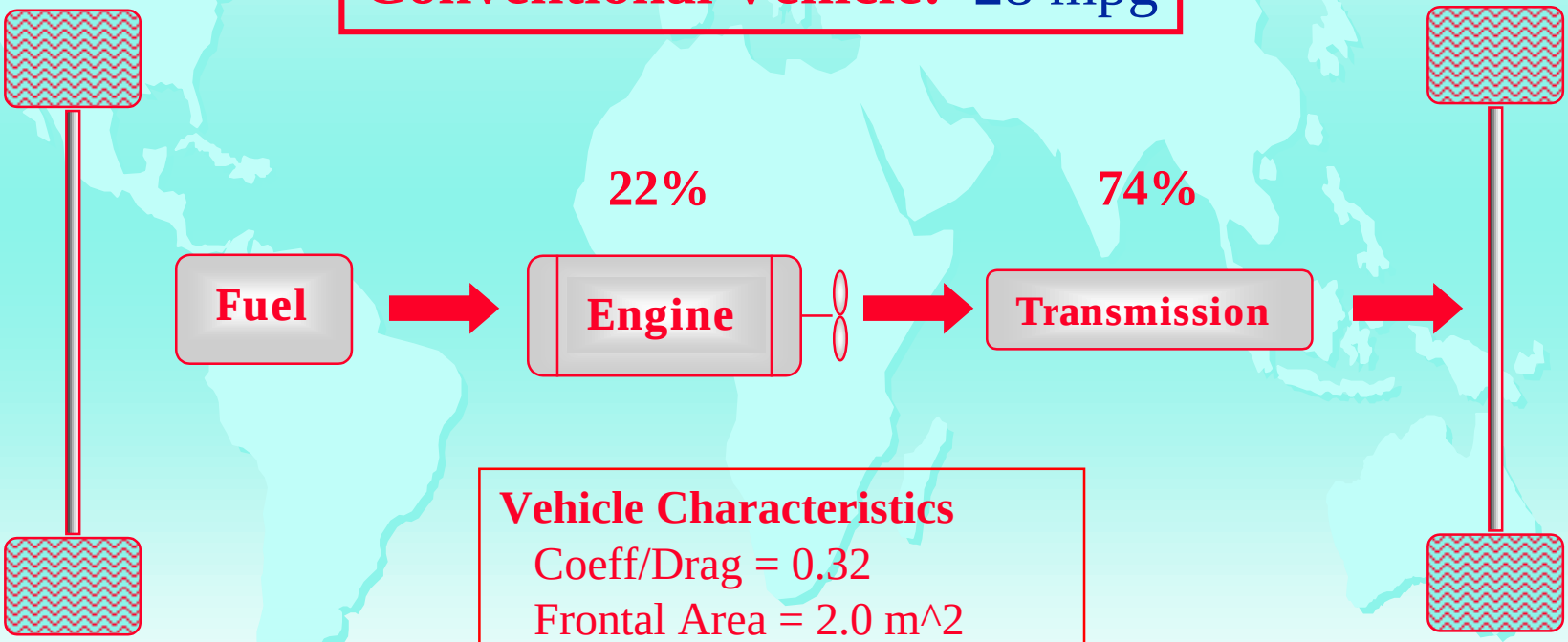


Transportation MUST Contribute *At Least* Its "Fair Share"

- *Magnitude:* where else to make up the 1/3 share?
- *Equity:* transportation energy consumers should share the responsibility
- *Politics:* all sectors face political obstacles; political risks are high if transportation is not included

Inefficiencies Drag Down Conventional Vehicle MPG

Conventional Vehicle: 28 mpg



Vehicle Characteristics

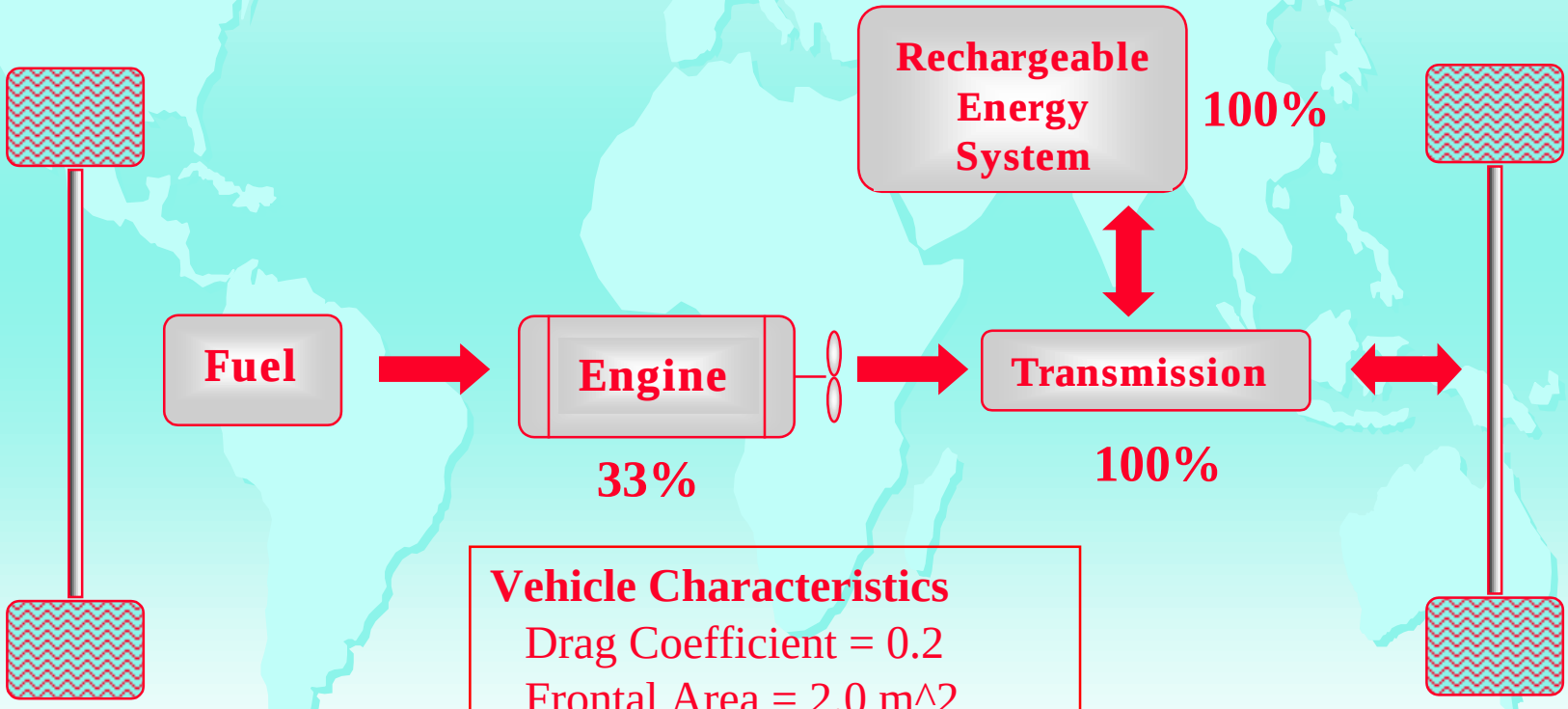
Coeff/Drag = 0.32
Frontal Area = 2.0 m^2
Coeff/Rolling Resist = 0.008
Mass = 3500 lb

Tracking the Size and Performance "Arms Race" (1988 - 1998)

Vehicle Attribute	Cars	Light Trucks	Combined
Fuel Economy	unchanged	-3%	-6%
Engine HP	+38%	+35%	+41%
0 – 60 Time	-17%	-13%	-16%
Weight	+9%	+12%	+15%

The Fuel Efficiency *Potential* is There for Hybrids

"Perfect" Hybrid with High Efficiency Engine: 141 mpg



Vehicle Characteristics

Drag Coefficient = 0.2
Frontal Area = 2.0 m^2
Coeff/Rolling Resist = 0.006
Mass = 3500 lb

How Will Manufacturers Apply Hybrid Technology?

- Robust regenerative braking systems?
- Combustion engine downsizing?
- Even more performance enhancements?
- Optimized for fuel economy and emissions?

The Federal Government's Role

Enabling Policy
(e.g., Vehicle Tax Credit)

R&D Partnerships
(e.g., PNGV)

Regulatory Policy
(e.g., Tier 2)

Environmental Hybrid Vehicles (EHVs)

Partnership for a New Generation of Vehicles

- Historic R&D partnership between domestic Big 3 and Federal Government

- Primary Goals:
  - Dramatically improve light-duty fuel efficiency without sacrificing emissions or utility
  - Enhance long-term productivity and competitiveness of U.S. domestic auto industry in a global economy
- $250M Federal annual budget

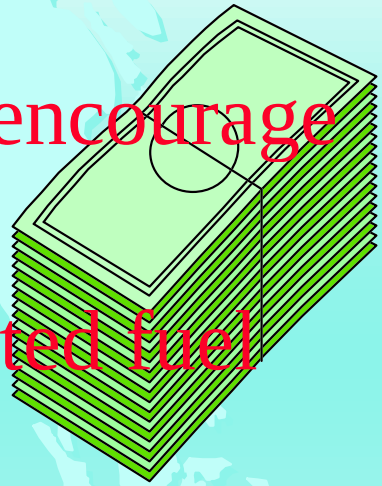
PNGV's Vision of the Car of the Future

- 80 miles per gallon
- Meets Tier 2 Federal emissions standards
- Meets all Federal safety standards
- Size, performance, cost of ownership comparable to today's midsize family sedans
- Leapfrog technology

Hybrids Are Central to PNGV

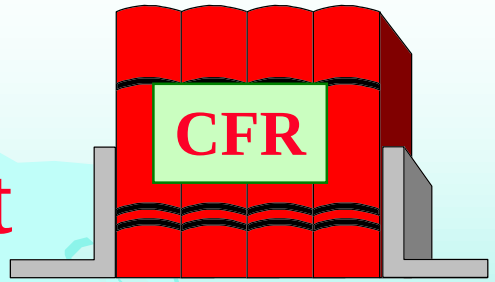
- Hybrid is the PNGV “powertain of choice”
- Rechargeable power source
  - moderates fluctuations in power demand on primary power plant
  - allows primary power plant to be optimized for efficiency and emissions
  - allows recovery of braking energy
- ICE & hybrid must work as a system

President's EV/Hybrid Vehicle Tax Credit



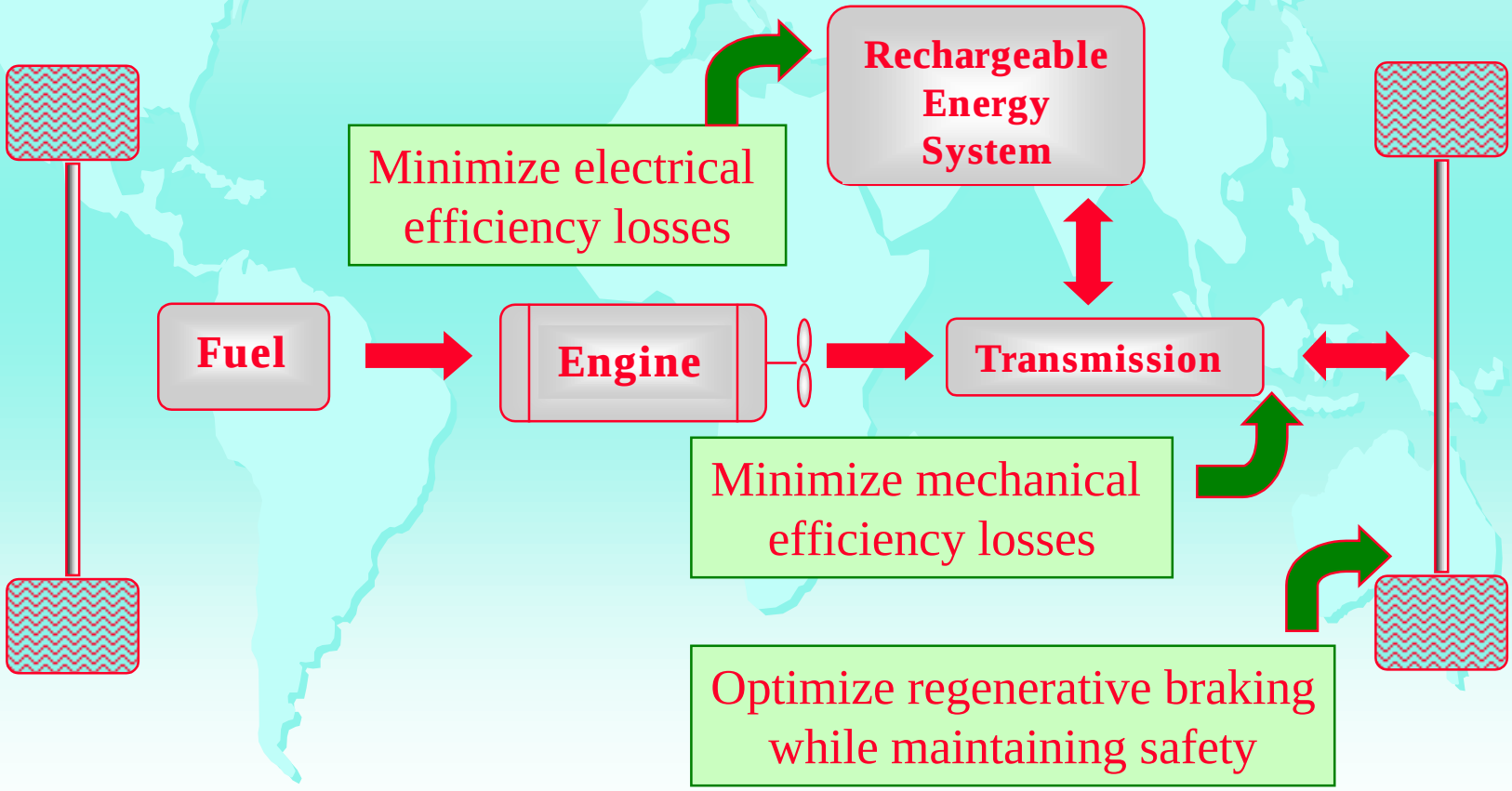
- Proposed by President Clinton to encourage hybrid and EV technologies
- Graduated credits based on projected fuel efficiency improvements
- Basis for constructive interaction on best approach and ultimate action by Congress
- Expect an active process this year

Tier 2 Proposal: Balanced Approach, Stakeholder Input



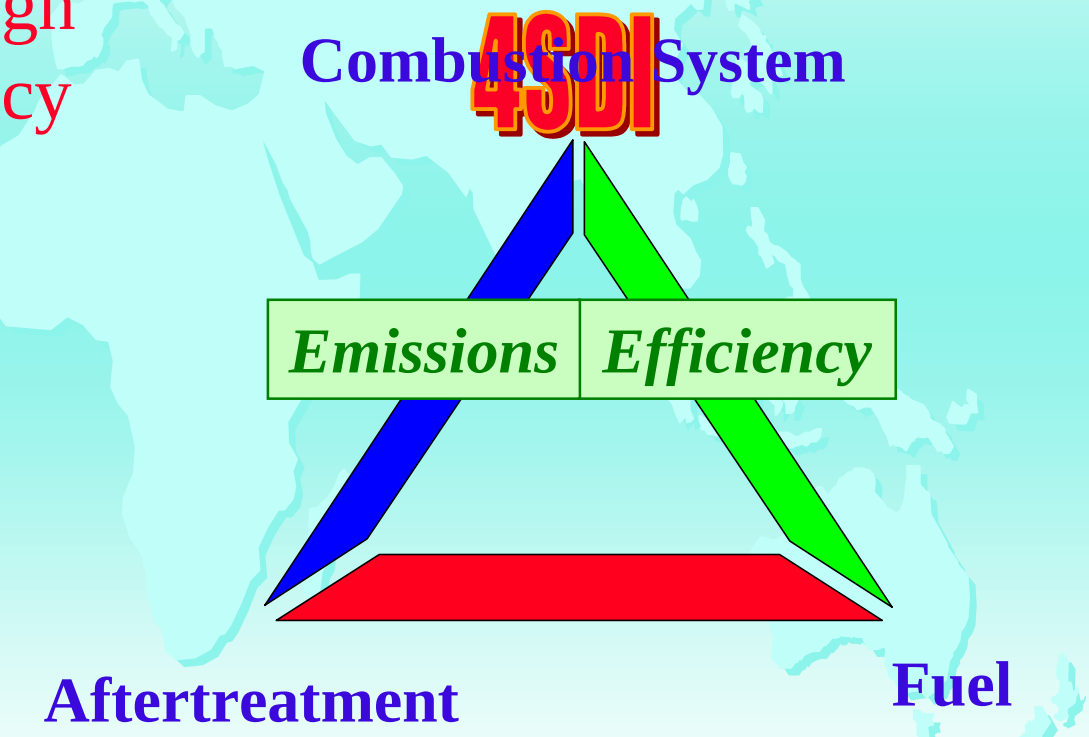
- All cars & light trucks (SUVs, minivans, pickups)
- Equal treatment of cars/light trucks, gas/diesel
- Phases in MY2004 - MY2009
- Vehicles certify into 7 emission bins defined by NOx, NMOG, CO, PM, HCHO standards
- Corporate average NOx standards
- NOx banking/trading
- Gasoline sulfur control; parallel diesel-S ANPRM

Hybrid Powertrain: Challenges



Hybrid Combustion: 4SDI is the Engine of Choice

- Best solution for high conversion efficiency
- Integrated systems with fuel and aftertreatment still necessary to reach efficiency and emissions goals



CIDI Challenges

- Achieving NO_x < 0.2 g/mi, < 0.07 g/mi
- Achieving PM < 0.04 g/mi, < 0.01 g/mi
- Weight
- Cost
- Carbon reductions *only if efficiency not traded for other attributes*

GDI Challenges

- Emission targets still challenging, but perhaps less than CIDI
- High efficiency not as obvious as CIDI, but probably still there
- Carbon reductions *only if efficiency not traded for other attributes*

Environmental Hybrid Vehicles: Here and Now?

Toyota Prius

DaimlerChrysler

Ford Motor Company

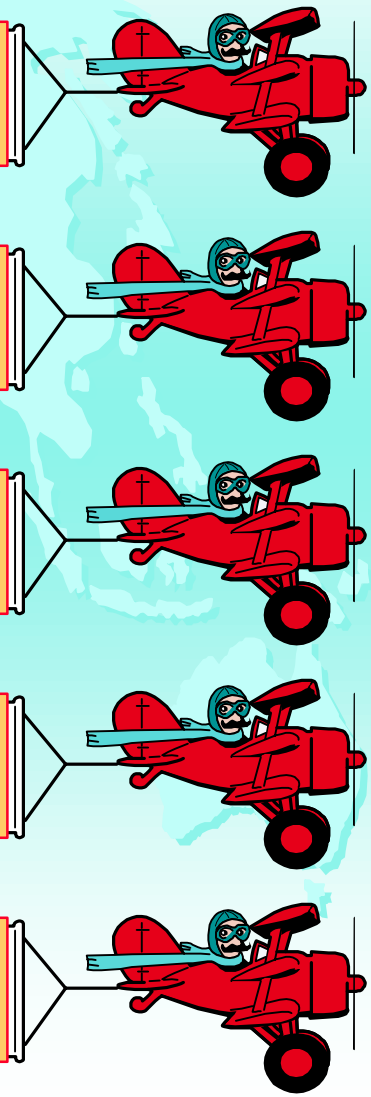
LSR Hybrid

GM General Motors

people in motion

Strategic Drivers for Change

- Leapfrog Technology
- Value to the Consumer
- Risktaking Businesspeople
- Powerful Government Policy
- Public Environmental Concern



We <u>can</u> achieve high efficiency in a hybrid system with low NOx and low PM -- an Environmental Hybrid -- an EHV